



# Engineering Services for Energy

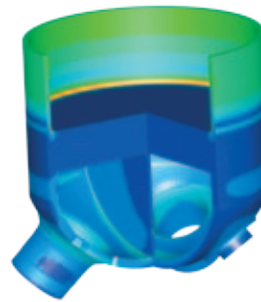
ESI has long-standing experience in consulting and engineering services with leaders in nuclear power worldwide. Our Quality Assurance program was established to meet the stringent needs of the nuclear industry. In addition to our ISO 9001 certification we comply with strict standards for nuclear application such as 10CFR50, NQA1, Q-N-100 and Q-N-300 (specific to AREVA), and SGAQ (specific to EDF).

## PROVE CONFORMITY WITH REGULATIONS

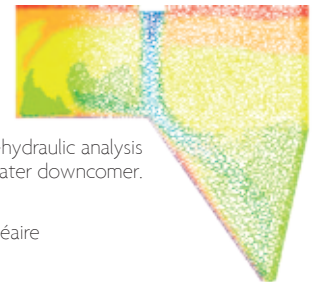
### Complex Thermo-Hydraulic and Thermo-Mechanic Analyses

“ COMEX NUCLEAIRE (CxN) completed in collaboration with ESI the Behavior Analysis Report for Replacement Steam Generators (RSG) provided by Mitsubishi Heavy Industries, Ltd. (MHI) for EDF French nuclear power plants. This notable work was carried out with a high level of quality using innovative approaches, such as SYSTUS functionalities allowing to complete 3D numerical models with as few hypotheses as possible. These studies include both complex thermo-hydraulic and thermo-mechanic analyses in order to demonstrate the equipment's full conformity with French nuclear regulation. ”

Dr. François Billon, Technical Director and Director of the MHI-CxN Partnership



3D Mesh of a Steam Generator's bottom part.



Thermo-hydraulic analysis in the water downcomer.

Courtesy: COMEX Nucléaire

## OPTIMIZE WELDING SIMULATION

### Realistic Multi-Pass Welding Simulation

ESI provides assistance to AREVA for the simulation of components welded on a large pressure vessel. This work is carried out within the MUSICA Project involving CEA, AREVA, Institut de Soudure, CETIM and ESI for the development and commercialization of simulation software for welding. This partnership aims at delivering robust simulation tools incorporating the thermal, metallurgical and mechanical behavior of metals, as well as certain chemical aspects for efficient and reliable modeling of the welding processes.

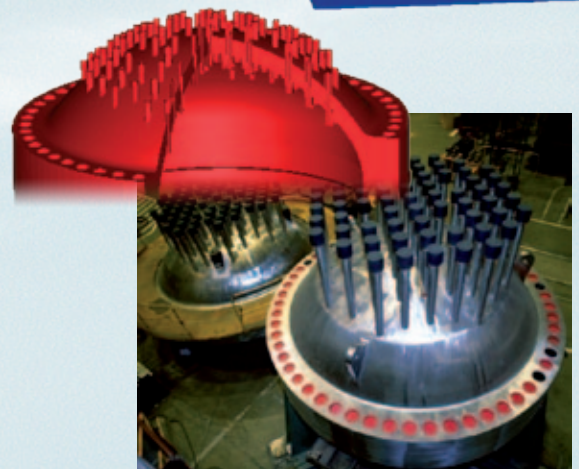
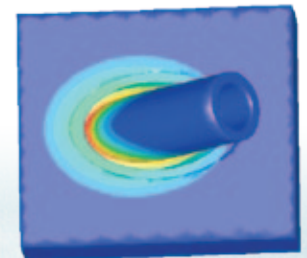
#### Challenge:

Validation of a fast and accurate 3D simulation methodology applied to a tube penetration attachment welded on a hemispherical head of a large ferritic pressure vessel.

#### Benefits:

- Thermo-mechanical computation leading to the development of a technique enabling accurate prediction of residual stresses.
- Time savings by a factor of 4 compared to a standard step-by-step simulation method.
- Reduction of distortions induced by the welding process in the tube.

MUSICA Project:  
AREVA test case.  
Simulation of components welded on a large pressure vessel.  
Courtesy: Areva



Lid of 900MWe reactor vessel.

Courtesy: Areva, R.Quatrain

## ASSESS SAFETY MARGIN

### Fracture Mechanics Analyses to Control Degradation Mechanisms

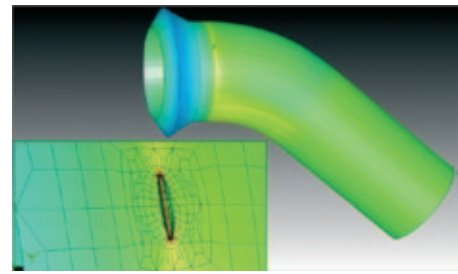
Assessing the aging resistance and the integrity of components is a key issue for the safety and the profitability of nuclear power plants. Therefore AREVA is constantly devoting large efforts to improve the accuracy of the fracture mechanics methods, to extend their domain of applicability and to develop associated software packages. In this case, the world leader in the electro-nuclear engineering field is relying on ESI to accurately model crack analysis in structures as well as crack propagation in bimetallic weldment.

#### Challenges:

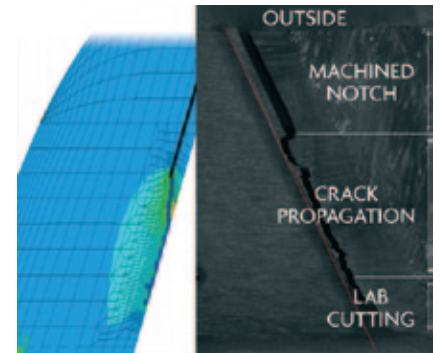
- Mesh complex cracked geometries with automatic adaptation to thermal computations.
- Kinetics of crack extension and ductile crack growth simulation.

#### Benefits:

- Development of a methodology to study rapidly the position, orientation and dimension of the crack.
- Applicability to other projects such as primary components, tube plates, pumps, seismic analysis...



Crack analysis of components.



Simulation of Crack Propagation in Weldment.  
Courtesy: Areva

## PREDICT BEHAVIOR OF LARGE WELDED ASSEMBLIES

### Electron Beam Welding for the ITER Vacuum Vessel Manufacturing

The aim of ITER is to show fusion could be used to generate electrical power, and to gather the necessary data to design and operate the first electricity-producing plant. The ITER vessel will be more than twice the linear dimensions of the largest existing tokamak vessel and over 16 times the mass.

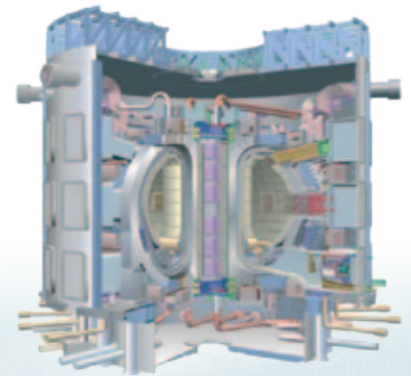
ESI supports AREVA and other industrial companies worldwide in the ITER international research project.

#### Challenges:

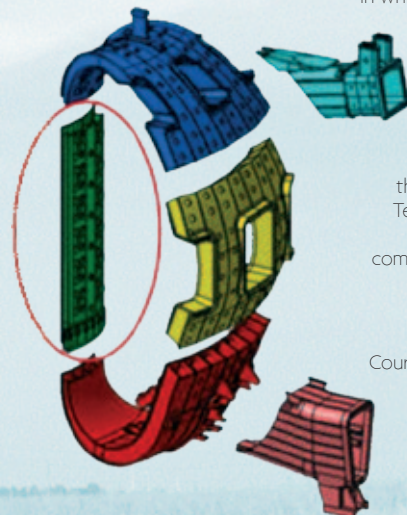
A refined and difficult study due to critical issues of fabrication technology: dimensional accuracy, welding distortions and achievable tolerances.  
The system shall be built in accordance with RCC – MR 2007 French Nuclear Code.

#### Benefits:

- Validation of the methodology to simulate the VATS mock-up.
- Very good predictions of the distortions correlated by experiments.



ITER Tokamak, in which strong magnetic fields confine a torus-shaped fusion plasma.



Assembly of the Vessel Advanced Technology Segment (VATS) incl. 55 components assembled by longitudinal and circular Electron Beam welds.

Courtesy: DCNS, AREVA